

SECOND REPORT ON GLOSSINA INVESTIGATIONS IN NYASALAND.

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(PLATES IV and V.)

Until 13th March I remained in the Proclaimed Area, then, as the weather conditions were very bad, and as moreover the grass had so overgrown all the paths, which are little used, that my movements were very much hampered, I removed to Fort Johnston at the southern extremity of the Lake, and have since been working in its neighbourhood.

Some preliminary tramps were necessary for the purpose of finding out the locality most suitable for the work, and accordingly in late March and early April, when the rains were just over, I took the opportunity of studying the distribution of *Glossina morsitans* on the east side of Lake Malombe; then to the south of Chingaras, a large village 25 miles south of the Fort on the main road to Zomba; and finally, along the west side of Lake Nyasa as far as Monkey Bay, 25 miles north of the Fort, where, as the fly was more numerous than elsewhere, I decided to continue the work.

The outcome of these expeditions was to revolutionise the ideas which I had obtained by reading as to the distribution of the fly at this season, for though in none of these localities were they as numerous as in the proclaimed area, isolated flies were found over a very wide range. Thus, in the course of a six hours' trek from Fort Johnston to Malombe, a distance of some 20 miles, I took five; two in the early morning when I first set out, many miles from where I subsequently found them to be numerous. On the journey from Fort Johnston to Chingaras, a distance of 25 miles, I took four in country hitherto considered free from them; and on the journey from Monkey Bay to Fort Johnston, which I have made several times, I have always been able to take one or two flies many miles from the locality in which I know them to be numerous. Such isolated flies are always very unobtrusive, and as they do not necessarily bite, though persistently following one, it is probable that they escape the untrained eye. In the proclaimed area the physical conditions of the country—the Lake to the east and a range of hills, devoid of trees, to the west—make the term "fly belt" applicable; but in the Fort Johnston district there was nowhere at that season anything approaching a hard and fast line marking the distribution of the fly, which indeed seems to occur under widely differing conditions.

Its distribution in varied types of country was well exemplified in the "fly belt" of the proclaimed area. Here on travelling due west from the Lake one passes first of all over a dambo [open swampy land], where of course there are no fly; then through scattered *Borassus* palms, which at a distance of about $2\frac{1}{2}$ miles from the Lake grow thickly, with low shrubs, and tufts of comparatively low wiry grass in between (Plate iv, fig. 1). The soil is very sandy, such being favoured by these palms; and here the fly begins. Further on, at a distance of two or three miles more, the sandy soil gradually gives place to a heavy black soil, very tenacious in wet weather, and there is a marked change in the vegetation, the palms becoming fewer and fewer till they give place entirely to large shade trees, baobabs and lower

bushes not of a thorny nature, while the grass is so high that for seven or eight miles one simply tunnels through it, with no possibility at all of seeing the surrounding country (Plate iv, fig. 2). Thorn trees then gradually appear and the grass gets lower, till at the end of another two or three miles one gets into thorn bush country, where there are few other trees. The soil here is inclined to be hard and clayey, though areas containing a considerable amount of sand are seen from time to time. With a gradual rise of the ground, beginning at about fifteen miles from the Lake, rocky outcrops appear, the thorn bushes becoming twisted and stunted in growth (Plate v. fig. 1); and finally, at an altitude of about 3,000 feet, only a few scattered shrubs are to be seen, so that practically open country is reached.

In all these varied regions, except the last, *G. morsitans* is to be met with, though in greatest abundance where the thorn bushes and the large trees are thickest.

When the grass is high, the flies, like the ticks, are most numerous along game and native paths; though, as is the case when the grass is low, their distribution varies from day to day.

Proportion of the Sexes.

My experience in this matter is the same as that of other observers, namely, that when the flies are bred out from pupae, the sexes emerge in almost equal proportions; and when the flies are captured, the males far outnumber the females. A theory which might account for this is that the females have different feeding habits from the males, possibly feeding better with an overhead sun, or when the sun's rays are more oblique. To test this a series of captures were made for several days at three different periods of the day, viz.: from 8 to 11, from 12 to 3, and from 3 to 6. The proportion of the sexes was found to be practically the same in each case.

A further theory which then occurred to me was that the distribution of the sexes in a given area might not be quite the same, and this theory seems to some extent to be supported by actual facts. Differential captures at the centre of a tsetse area, and at its margins where the flies are more scanty, do show, though statistics are as yet meagre, that the females are more abundant at the outskirts; and in the search for pupae in regions which the fly has temporarily vacated, it has been my frequent experience to be assailed by a solitary pregnant female.

There are very definite reasons why the female flies should to some extent shun the society of the males. As I have before remarked, and have since repeatedly observed, coitus takes place as a result of capture without preliminary courtship. Moreover, when, as often happens, little knots of flies in a confused buzzing swarm of four and five appear suddenly in one's vicinity, repeated captures have shown the group to contain one female, and one only, the obvious interpretation being that the female wishing to feed, has been chased by the males. Furthermore, on putting a newly emerged female, even with its wings still flaccid, into a jar containing males and an adequate supply of the other sex, it is almost the rule for the female to be seized immediately by one of the males, which sooner or later after a struggle accompanied by loud protest effects coitus; and it occasionally happens that two males will seize the same female.

In captivity even females in an advanced state of pregnancy are not secure from the violence of the males, and as abortion is so frequent with captive females, it seems

possible that this may conduce to it. Latterly, therefore, it has been my practice to keep such females apart from the males, the results obtained justifying the correctness of the conclusion. It often happens also that a male will become securely locked to a recently dead female, and Dr. J. B. Davey, of the local medical service, informs me that he has repeatedly witnessed a similar occurrence.

These facts undoubtedly indicate the necessity for the pregnant female to seclude herself, when once fertilised, from the further attentions of the males; hence the unequal proportion of the sexes among captured flies.

If this supposition be correct, a comparison of the proportionate numbers of the sexes caught during the breeding season, and when breeding is not going on to so great an extent, should yield evidence bearing on the question. There are not, so far as I am aware, statistics dealing with the breeding habits of the fly in Nyasaland, and as the seasonal conditions are probably different from those of Rhodesia, an examination of such data obtained there is not likely to shed much light on the question here. I am, however, sure that the flies just now in the early dry season [beginning of June] are breeding more freely than they did when the rains were on in February, and a consideration of the relative proportion of the sexes taken over a given period of time at the two seasons does afford some slight evidence in support of the supposition, the females in February forming 15 per cent. of the total captures, and in May 5 per cent. The actual figures are given in the following table:—

Table showing Proportion of Sexes in captured G. morsitans.

Locality.	Date.	Males.	Females.	Remarks.
Lingadzi	3.ii.15	150	16	Wet season.
.. ..	4.ii.15	129	19	..
.. ..	5.ii.15	231	22	..
.. ..	6.ii.15	111	24	..
.. ..	7.ii.15	142	32	..
.. ..	8.ii.15	128	21	..
.. ..	10.ii.15	130	25	..
.. ..	11.ii.15	183	35	..
.. ..	12.ii.15	163	23	..
.. ..	13.ii.15	116	11	..
.. ..	15.ii.15	118	12	..
.. ..	16.ii.15	186	24	..
	Total ..	1,788	264	15 % (almost) of females.
Monkey Bay	11.v.15	143	5	Dry season.
.. ..	12.v.15	282	28	..
.. ..	13.v.15	136	4	..
.. ..	14.v.15	76	11	..
.. ..	16.v.15	113	10	..
.. ..	17.v.15	103	3	..
.. ..	18.v.15	128	5	..
.. ..	21.v.15	80	4	..
.. ..	22.v.15	215	5	..
.. ..	23.v.15	99	5	..
.. ..	24.v.15	152	4	..
.. ..	26.v.15	71	0	..
	Total ..	1,598	84	5 % of females.

Predaceous Enemies.

A species of dragonfly (*Orthetrum chrysostigma*, Burm.) the male dull blue in colour, the female greenish blue has now been found to prey on *morsitans*. In February, in the Lingadzi district, I saw one of these dragonflies, which had been following and hovering round the party of six boys with me, suddenly swoop down and take a tsetse from the back of one of the boys who was stooping at a pool to drink, its movements being extremely rapid. It settled on the grass near by and commenced to devour its prey. Later on I saw a dragonfly of the same species take a *morsitans* which had rested on a blade of grass, though again I was unable to see whether the capture was effected on the wing or not; and on the following day I saw another capture a tsetse off a boy. A fact of importance in all three cases was that each dragonfly accompanied our party for some little distance, obviously expecting to find its prey in our vicinity.

I have further studied these dragonflies in relation to *morsitans* in the Monkey Bay district. They have been observed repeatedly to flit round passers-by as if in search of prey, settling near by if unsuccessful. When a number of people are walking in Indian file, it is quite common for the insects to make a search round each, often following on a short distance behind, and I have without any difficulty caught a number of specimens with their prey, in most cases tsetses, taken in the neighbourhood of natives accompanying me.*

When a dragonfly has appeared at such times as there happened to be no tsetses about, further light as to the object of its presence has been obtained from time to time by flicking off one's hand a tsetse with one wing clipped. So fleet are they on the wing that in a number of cases the tsetse was seized before reaching the ground. By this method it was ascertained that tsetse-flies, whether half starved or replete with freshly ingested blood (either from a goat or a fowl) were equally acceptable to the dragonfly, and after eating a replete tsetse the dragonfly has been found to have the blood smeared abundantly over its face and jaws. The insect is indefatigable in its work, and both sexes are to be found on the move in glades, in open grass country, and on rocky barren soil far from water, whether early or late, in sunshine or bad weather. The females feed and oviposit readily in captivity, the eggs, which are numerous, being arranged in irregular masses.

I have kept a look out to determine whether any other species of dragonflies habitually prey on tsetses. Only one other instance occurred, and in this case the insect (*Crocothemis erythraea*, Brullé) handled the tsetse-fly so clumsily, gradually slipping down and right round the grass stem to which it was clinging, in a vain endeavour to hold its prey and support itself at the same time, as to convince me that it was quite a novice with tsetses.

Observations on the Larvae of Glossina.

As has been already noted by previous observers, the newly born larva is covered with a clear slimy secretion, and a theory has been advanced that the purpose of this is to cause earth to adhere so that the pupae are less readily recognised by

* [Dr. Lamborn has sent notes of 21 cases in which he saw these dragonflies take tsetses on 23rd and 24th April and 3rd-12th May 1915.—ED.]

scratching animals. This supposition has not seemed to me to be tenable, seeing that one never finds such a covering, however carefully one digs up the pupae; and moreover, though a certain amount of dust does cling to the pupa, it is invariably in the form of minute particles only in the neighbourhood of the intersegmental rings.

A more likely supposition has seemed to me that the secretion might have a protective function, the period between the birth of the larva and its burying itself in the ground, during which it crawls on the surface, being probably the most critical in the life-history of the fly. Ants are invariably found in the breeding places, and as they depend so largely on insect food, a series of experiments have been conducted with a view to finding out the attitude of various species towards the larvae. Those selected first for the experiment were a small black Myrmicine [*Pheidole megacephala*, F.]. These usually run about singly, and though repeated trials were made, in no single instance did a solitary ant, or even two or three together, attempt to molest the larva, the usual procedure being for an ant, having examined it with its antennae, to back away and run off on other business. When, however, a larva was placed close to a nest of these ants well stirred up, several invariably attacked it, but in a short time relaxed their hold and cleaned their antennae, though others then seized it. The same results were obtained with another Myrmicine ant *Pheidole lieugmei*, For.].

In the case of another ant [*Cremastogaster chiarini*, Emery], a larva was placed close to a large party engaged in the work of dismembering a big cockroach. Two or three having investigated it with their antennae retired, but after a time one large one seized it by the black prominences at the posterior end and held on for some seconds till three or four others came up and gripped it elsewhere. It was obvious that they were by no means happy with their prey, for they let go one after the other, cleaning their mandibles, but by and by again seized it. These ants are not, however, found in the breeding places, as they favour more open situations.

The only really definite results were obtained with the small Ponerine ants [*Euponera senaarensis*, Mayr],* one of which on several occasions uncompromisingly seized the larva and ran off with it.

From these results I think that a reasonable inference may be drawn that the secretion is protective against such ants as are usually found in breeding places. It is probable also that it is of material advantage in protecting the delicate cuticle from injury as the larva makes its way down to its future resting place in the soil.

Parasites of *Glossina morsitans*.

The large number of Mutillid wasps in the Lingadzi district attracted my attention from the first, and I endeavoured during my earlier days here to parasitise tsetse pupae with them, but without success. Long series of the smaller species, which seemed suitable, have been sent home.

In late May, however, two Mutillids, a male and a female, which I have since learnt from the *Bulletin* are *Mutilla glossinae*, Turner, were bred out from pupae found in the vicinity of Monkey Bay, and a good series have now been obtained, 6 males

* [Mr. W. C. Crawley kindly identified the ants forwarded by Dr. Lamborn.—Ed.].

and 10 females having been bred out. The tsetses which have emerged from the 1,143 living pupae which I have obtained since 10th April number 54 males and 71 females.

The appearance presented by a pupa-case from which a Mutillid parasite has emerged seem to me characteristic and unmistakable, though a contrary opinion has recently been expressed (Eminson, quoted in Bull. Ent. Res., v, p. 382). On taking such a case in the fingers there is, owing to the presence of the *Mutilla* cocoon within, a sense of greater solidity than when a fly has emerged, and it is possible by gentle pressure to crumble away the wall of the puparium so as to obtain the cocoon, a light chestnut-coloured structure composed of several layers of a very tough silky-looking material. The orifice of exit is usually much smaller and has a serrate edge, instead of the larger clean-cut fracture produced by the emergence of the fly, owing to the parasite having nibbled out a circular cap, and one can always see the walls of the cocoon within. In the course of time the cocoon tends to shrink, the result being that it draws in with it the margin of the hole of exit in the pupa-case, so that this is no longer circular but somewhat oval, a condition never seen in the case of a normal puparium.

There has been no difficulty at all in dealing with the Mutillids in captivity, for all, except two, one of which was accidentally drowned, are still alive now, one or two of the earliest specimens being several weeks old. The original male placed in a box with the female shortly after the emergence of the latter manifested the greatest excitement, running about with its antennae on the ground on the track of the female, which it overtook after a considerable chase and immediately seized, pairing taking place almost at once. It is noteworthy that in the course of the chase it ran repeatedly very near to the female, but being off the fresh track did not detect it, the sense of sight being evidently of very little help to it in the matter.

Various pairs have been kept in captivity in jars containing a number of tsetse pupae buried in earth, in the hope that the females would sooner or later parasitise them. This expectation seems likely to be fulfilled, as on 30th May the first female, which emerged so long ago as the 3rd of that month, was actually witnessed ovipositing in one of the pupae. As the manner in which oviposition was effected presented features of interest, I jotted down at the time a full note concerning it, which I now transcribe:—At 5.45 p.m., on coming into camp from a day's trek, I removed from inside a box, which had been closed all day, a jar containing the *Mutilla* female, no. 1, and a number of tsetse pupae, mostly buried in earth, though one or two were on the surface. On the top of one of the latter the *Mutilla* was seen. It remained still a few seconds, then precipitately vanished beneath a lump of earth, as is their habit when alarmed. In a few minutes it came out into the open again cautiously, and after examining with its antennae some pupae near the one on which I had first seen it, started, with its head facing the tail end of the pupa, to whittle away with its jaws at a point midway between the two poles with such energy as to rock it. Its antennae were crossed and below its head. After five minutes' work in the horizontal position it gradually raised itself vertically, with its head down on the pupa, supporting itself against the side of the jar, so that a full view of its movements with a lens could readily be obtained. Extremely fine movements of the jaws in and out took place with great rapidity and with such

delicacy that unless one's attention had been attracted by corresponding movements of the labial palpi the operations in progress would have been undetected. From time to time a sharp turn of the head through a quarter of a circle on each side also went on.

After half an hour's work the *Mutilla* retired a short way from the pupa and, resting on its side, cleaned its antennae and rubbed its legs together, but then manifested some uneasiness at the light, for at this point I had to watch it by lamp light, and concealed itself. But when the light was very much shaded, it returned to the pupa, put its head to the site of its previous operations, where with a lens I could see a small breach of surface, and then gradually raising the hinder part of its body so as to rest again on its head, recommenced work, its antennae being this time in front of its head, but resting on the pupa. Occasional movements of anteflexion of the abdomen then took place, as if the insect were preparing for oviposition, and finally, after at least an hour's work, the insect resumed the horizontal attitude on the pupa, and having examined its work advanced so that its hinder end came somewhere over the breach. It then moved to and fro, feeling for the exact spot, and then remained still, doubtless in the act of oviposition, running away a few seconds later.

Though the female worked so indefatigably, so tiny a puncture was produced as to be barely visible except in a certain light to the unaided eye, and it appeared moreover as if definitely sealed by the insect with some secretion after oviposition. This may possibly be a very important part of its final operations, as on several occasions I have found an exuberant fungus growth, brown in colour, sprouting at little fissures accidentally produced in tsetse pupae. By and by I hope to be able to study this further.

I should perhaps add that the night when the *Mutilla* was working was bitterly cold, a rather surprising fact, seeing that as a rule these insects are so lethargic except on bright sunny days.

I have now examined carefully all the pupae to which this female has access, and seven out of the twenty show this evidence of attack. There is therefore every reason to believe that the *Mutilla* can be raised experimentally in some numbers and without any great difficulty in the laboratory. Their hardiness, their activity in finding food for themselves and their longevity make them singularly easy to deal with, so that I expect shortly to be able to submit a further report on the subject.

In regard to their general habits, they do not as a rule become active till the middle of the afternoon, remaining until then hidden beneath objects on the top of the ground, or buried beneath the superficial layers of the soil. The female is an adept at burrowing, and the male in pursuit of her does not hesitate to force his way into the soft earth. Both sexes run with extreme activity, the male being unusually loth to take to flight for a winged insect. The females in captivity soon lose the quality of shyness, which is so marked during the first day or two after emergence, and will then run about unconcernedly, even though one is moving objects in the jar, almost as if they had learnt that they were unlikely to be molested.

A species of Bombyliid fly (*Thyridanthrax abruptus*, Lw.)* a striking-looking insect, quite distinct from the *Villa lloydi* found also to be parasitic on *morsitans* pupae in Rhodesia, has been bred out from *morsitans* pupae here, three specimens having been obtained. The first of these insects was discovered in early May in a jar containing a number of tsetse pupae which had been buried beneath the earth. The pupa-case of the *Thyridanthrax* was found on the surface, and I therefore concluded that perhaps the pupa, having escaped notice, had been in the earth all along and had no connection with the tsetse pupae. But since this I have been keeping my pupae in rice to prevent them from rolling about when the boxes are moved, and in these I found two more of the Bombyliids a short time ago, their puparia being far removed from the tsetse pupae which they had originally occupied. The empty tsetse puparia differ in no way from those from which tsetses have emerged, other than in the absence of the cuticle which is found in the latter.

This Bombyliid is by no means uncommon in the fly area, especially at Lingadzi, so that I have been familiar with its appearance almost from the very first. I am endeavouring to proceed further with an investigation into its habits.

Within the last few days two nice-looking Chalcids [*Stomatoceras micans*, Wtrst.], large insects with black markings on the wings, have emerged from tsetse pupae through an opening situated in each case close to the tubercles at the posterior end of the puparium. These also are thriving in captivity, but unfortunately appear both to be of the same sex.

In connexion with the question of Chalcids, I found in April in cattle droppings a large number of pupae of a little Muscid [*Musca* sp. nov. ?] common in houses in this country, and having bred out numerous small Chalcids [*Spalangia* sp.] from them, endeavoured to parasitise tsetse pupae with them, but without result, so far as I have yet been able to judge.

A fourth species of parasite, an apterous insect, † has also been bred out from a tsetse pupa.

Examination of the living pupae recently collected, 1,143 in all, affords evidence as to the probable parasitism of a small number, small marks like punctures being visible with a high power lens, and a study of the empty cases found at the same time, numbering 9,762, has afforded some statistics thereon, for owing to their chitinous nature and the sheltered positions in which they are placed it appears to be some time before the empty cases suffer by exposure. By far the greatest number of cases (no less than 8,543) had given exit to perfect flies; for though there is no means of differentiating between normal pupae and those parasitised by Bombyliids, the latter seem to be in so small a minority as to be almost negligible from the statistical point of view; 351, or 3½ per cent., showed that they had been parasitised by Mutillids, the features characteristic of which have already been

* [This species was bred from a *G. morsitans* pupa in Southern Rhodesia, in November 1912, by Mr. R. W. Jack. In Nyasaland, it was found in Mombera's district by Dr. H. S. Stannus, and in North Nyasa by Dr. J. B. Davey. It has also been received from Embu, Mt. Kenia, British East Africa (*G. St. Orde Brown*) and Miinna, N. Nigeria (*Dr. J. J. Simpson*).—ED.]

† [This is a new and remarkable Chalcid, which will shortly be described by Mr. J. Waterston under the name of *Eupelminus tarsatus*.—ED.]

described, the parasite having in practically every case escaped at the cephalic end ; 107, roughly 1 per cent., were intact, except for a pin-point hole at one side, produced in all probability by the escape of some tiny parasite, possibly a Chalcid parasitic on the Mutillid, for a few of these which were broken open showed the remnant of the cocoon of the latter ;* 264, roughly 2 per cent., show larger rounded holes produced by the escape of a parasite, some at the posterior end, others to one side, the insect being in all probability one of the large Chalcids. Some twenty, a few of which had contained Mutillids, showed evidence that the pupal contents had been eaten from outside ; and 477 were so damaged that it was impossible to form any opinion as to their history.

No parasites whatever have as yet been bred out from pupae obtained in the proclaimed area,† all that have been obtained hitherto having emerged from pupae found in the vicinity of Monkey Bay, a fact which may explain the numerical superiority of *morsitans* in the former region.

Breeding places.

Until April the search for breeding places had been almost without result, five pupae only having been found in hard clayey soil. But since then they have been obtained in large numbers, as the result of realising that the condition of the soil is one of the all-important factors in determining whether or not a particular spot will be selected by the female.

As pointed out by Mr. Lloyd, the fly seeks some relatively dark and shady spot. Many such are to be found in a tsetse area, mostly under fallen trees ; but in my experience, which is now considerable, being based on an examination of 512 breeding places, few, if any, pupae will be found unless, in conjunction with the shelter, the soil is likely to be dry at all seasons, having no hard top crust, such as is formed under the influence of moisture and sun, and containing sand and decaying wood or other vegetable matter so as to make it light. In nearly every instance the breeding places have been situated beneath a fallen and well decaying tree, which has been prevented by some of its limbs from actually touching the ground, and is of such girth as to keep an area beneath it shaded and free from moisture. The soil in such a place being leavened by humus becomes light and friable, so that the larva can have little difficulty in making its way into it.

Very few pupae have been found in hard clayey soil beneath trees, and as it has been found experimentally that the larvae have very weak boring powers, being unprovided with bristles, their occurrence in such situations is probably purely accidental, the parent fly having possibly failed to find a suitable place in time for the birth of its offspring. Such soil, moreover, in the dry season dries almost as hard as stone, needing such considerable force to break the top crust as would render it almost impossible for the newly emerged fly to break its way to the surface.

* [A large number of these Chalcids were bred subsequently by Dr. Lamborn from a tsetse pupa and proved to be *Syntomosphyrum glossinae*, Wtrst. There seems little doubt now that this species is harmful, being a hyperparasite of *Mutilla glossinae*.—ED.]

† [If this observation is confirmed, it may prove to be of considerable practical importance, for the introduction of parasites from Monkey Bay would probably in that case have a material effect upon the numbers of the fly in the proclaimed area.—ED.]

Some few pupae have been found under trees in accumulations of dead leaves on the surface of the ground, but so few, that this again is probably purely accidental. Pupae in such situations seem to stand little chance of survival, for repeated experiments made by exposing bred ones in similar surroundings in the hope of getting them parasitised, have resulted in the loss of the majority, some undiscovered insects, possibly cockroaches, which one finds not infrequently, having eaten out the pupal contents.

As has already been pointed out by workers in Rhodesia, pupae may be deposited in cavities in dead limbs of trees, a certain amount of soil, the result of the admixture of earth originally brought by termites with wood debris, being invariably found in such situations (Plate v, fig. 2).

The question of soil in the various breeding places has been studied, but no special sort seems to be favoured, the chemical constitution being immaterial, so long as the soil is friable. All the trees also, in relation to which pupae have been found, have been carefully examined with a view to ascertaining whether one species more than another is favoured by the fly. In the majority of cases decay has been so far advanced that the determination has been out of the question, but in 48 instances specimens of the foliage, representing at least fourteen species, have been obtained and are available. In five cases a few pupae have been found under the shelter of a fallen *Borassus* palm.

Further study of the question has shown that the presence of a dead tree is by no means essential, for in certain parts of the Monkey Bay district breeding grounds sheltered by overhanging rocks have been found, each yielding from two or three to as many as ten pupae (Plate vi, fig. 1).

Attention has been paid to the orientation of all these places, the conclusion arrived at being that this is immaterial, all that is apparently required being that the breeding places should be sheltered from the overhead sun.

The conclusions arrived at from my study of the question are that the only essentials inducing a female tsetse to select a particular spot are looseness of the earth and shelter. In Nyasaland, as in Rhodesia, the situations most favoured are near game and native paths, and near water-holes (Plate vi, fig. 2), whereby the newly emerged fly is in the most favourable situation for obtaining food in the shortest possible time after emergence. Beyond this, the choice of a site by the parent fly is not in my opinion influenced by any special type of soil or of vegetation. The insect fauna in breeding places has been studied as digging has proceeded. It is never very numerous, the only frequent occupants of such places being small blackish Myrmicine ants [*Pheidole megacephala*, F.] and the larvae of ant-lions. Small cockroaches and their oothecae are not uncommonly found, and also the pupa-cases of the large Ponerine ant, *Paltothyreus tarsatus*, F., which insect is frequently seen transporting its pupae and probably deposits them in such a situation as being sheltered.

It is by no means uncommon also to find small lizards and geckos, which doubtless take some toll of pregnant and newly emerged flies. But the fly is able to run with such great activity for a short distance as to make it a matter of some difficulty

to secure a newly emerged insect with one's fingers. This doubtless favours the escape of such insects, and of the pregnant females, which take to flight unwillingly and fly heavily.

No evidence has been seen that any scratching animals habitually seek food in such places, the various Gallatores—francolin, partridge, and guineafowl—which abound in the tsetse areas, preferring more open places, especially where game is in the habit of resting.

Early in June I returned to the proclaimed area for the purpose of ascertaining whether pupae had been deposited under trees already felled in the district.

With a view to minimising the numbers of *morsitans* along the road running west from Domira Bay, the Government cleared in the middle of last year an area averaging a hundred yards in width on either side for a distance of about eight or nine miles. I may remark incidentally that in January the Resident, who was responsible for the clearing, gave it as his view that the measure had been productive of some benefit. The Medical Officer however, who knows the district well, expressed a very contrary opinion, and I myself found the flies abundant in places and extremely troublesome, though the country was a blackened wilderness as a result of grass fires. Later on, in March, the tall grass and the new shoots put out by the tree-stumps formed abundant shelter for the fly.

By the clearing process all trees, whether large or small, were cut off at a height of about two feet from the ground, and many, which had fallen before the trunk had been completely severed, rested at one end on the stump, a condition which seems to form beneath an ideal kind of breeding place for the fly. Hundreds of such places now exist there, and as there seemed to be a strong probability that the fly might use some of them as breeding places, I have examined a large number and have ascertained this is actually the case. Pupae in small numbers were obtained under a large number of trees—on 8th July for instance, an unusually good day, 30 living pupae and 162 pupa-cases were found—and doubtless as time goes on and the earth under the trees becomes looser, more and more will be obtainable, for the grass fires of this year have done little towards consuming these trees, though they were felled as long as a year ago. My observations there confirm my previous experience, that no special tree is favoured by the fly, which conclusion is further supported by the discovery of a few pupae in wood ash beneath trees which have been partly burnt by grass fires. There is thus no question as to the feasibility of constructing artificial breeding places.

A further fact of importance is that many of the pupae are to be found in a part of the area from which, concomitant with the drought, the fly has temporarily receded, a point which any scheme for dealing with the fly will require to take into consideration; and there is also the possibility that pupae so situated may remain quiescent in the soil during the greater part of the dry season, the flies emerging and repopulating the area when a change of season takes place.

A large number of tsetse pupae found at Monkey Bay in late April, ten weeks ago, are still alive, so far as I have been able to ascertain by opening one or two,

and indeed every day or two a fly comes out from among them. The discrepancy in the accounts given by other workers as to the length of pupation (47 to 53 days, Kinghorn, in Bull. Ent. Res., ii, p. 295; and 23 days on an average, Lloyd, in Bull. Ent. Res., iii, p. 95) would seem to support the conclusion. In February of this year (the wet season), a family of flies (*Sarcophaga* sp.), which I bred from one parent with a view to studying parasites, all emerged on the same day and at the same hour, whereas from the pupae of a second family bred recently in the dry season only five out of twenty-three have as yet come out, and those three weeks ago; this strongly suggests that aestivation is proceeding. On the west coast of Africa it certainly occurred in the case of a Muscid allied to *Lucilia*, and was of course the regular occurrence with various species of Lepidoptera.

Flight Experiments.

In passing from a *morsitans* area into country apparently free from them, whether bush or open country, it has always seemed to me that the same tsetse flies which have been hovering round continue to follow for a considerable distance. With the object of deciding whether such flies do really attend one and are not chance new-comers, a series of experiments have been conducted, consisting in liberating marked flies at a definite point, and then after a walk to various distances capturing all those in the immediate neighbourhood.

The results obtained afford positive information on the point, but in regard to the actual numbers of the flies recaptured there are of course several conceivable fallacies. For instance, possible variation in the walking pace on each occasion, though it was as uniform as possible; possible impairment of the insects' powers of flight, as a result of injury during capture; the influence of wind and of climatic conditions on each occasion, etc.

The first series of experiments, which I give below in table form, was conducted in the neighbourhood of Domira Bay and consisted in releasing the flies where most were originally taken, in palm country towards the east, and then returning to the Lake shore, a distance of $2\frac{1}{2}$ miles, mostly across dambo [open grass land] and capturing as many as possible. On every occasion a breeze was blowing from the direction in which my party was proceeding.

Date.	No. of males released.	No. of males recaptured.
2.iii.15	20	3
3.iii.15	20	1
5.iii.15	20	4
6.iii.15	20	3
8.iii.15	20	1
9.iii.15	20	2

The second series of experiments given in detail in the table below, was carried out at Monkey Bay and consisted in liberating marked flies at the outskirts of bush country favoured by tsetses and then recapturing as many as possible at definite distances along a native path, which, like all these paths, was very devious, winding in and out among thorn bushes.

In connection with the whole question it is noteworthy that motor cyclists coming into Fort Johnston commonly assert that the flies, which are abundant some thirty miles to the south along the Zomba road, settle on their backs and are so brought into the Fort. Residents confirm the statement, and it is therefore possible that the large increase of motor traffic, which has taken place as a result of military measures in the country, may be indirectly responsible for the high mortality of the cattle from trypanosomiasis which has occurred during the past few months at the Fort, and may account for the occasional discovery of a stray tsetse in the houses there.

Date.	No. of males released.	No. recaptured.	Distance traversed.
12.iv.15	100	13	$\frac{1}{2}$ mile.
13.iv.15	100	16	1 "
17.iv.15	100	3	$1\frac{1}{2}$ miles.
18.iv.15	100	20	$1\frac{1}{2}$ "
22.iv.15	100	12	$1\frac{1}{2}$ "
23.iv.15	100	19	$1\frac{1}{2}$ "

I have made a third series of flight experiments in the proclaimed area, releasing marked male flies, as before, at a spot two miles south of the Lipimbi river, at an altitude of 1,950 feet, and recapturing as many as possible in the region from which they had been removed, namely Lingadzi, about five miles distant in direct line, with an altitude of 1,700 feet. The country which they had necessarily traversed in their return consists of thin woodland composed of thorn and other low trees growing in rocky arid ground, in which area flies have from time to time been found, though never in any great numbers, the region to which they returned being characterised by the greater fertility of the soil, which is far less rocky and sandy, by the greater luxuriance of a similar type of vegetation, and by the presence of a greater amount of surface water, as a result of which game is much more abundant.

In making these experiments every precaution was taken to guard against possible fallacy. The flies were liberated by placing the cage in a tuft of grass before opening the door, by which means it is possible for the person conducting the experiment to get away to a distance before any flies are able to follow. In no case did the person releasing them return to the tsetse area, and there was very little probability of any flies returning on the backs of chance passers-by.

The results of these experiments are given in the following table:—

Flies released at Lipimbi R.			Flies recaptured at Lingadzi.		
Date.	No. of flies, all males.		Date.	No. of flies recaptured.	
3.ii.15	..	146	4.ii.15	..	3
4.ii.15	..	129	5.ii.15	..	1
5.ii.15	..	231	6.ii.15	..	1
6.ii.15	..	111	7.ii.15	..	2
7.ii.15	..	142	8.ii.15	..	1
8.ii.15	..	121	10.ii.15	..	1
10.ii.15	..	130	11.ii.15	..	1
11.ii.15	..	183	12.ii.15	..	2
12.ii.15	..	163	13.ii.15	..	1
13.ii.15	..	116	15.ii.15	..	2
15.ii.15	..	118	16.ii.15	..	1
16.ii.15	..	186	17.ii.15	..	1

General Observations.

I have repeatedly seen flies settled on wet sand, for the purpose I imagine of drinking, though as the fine proboscis only is lowered while the palps remain in the usual position in front of the head while the insect is feeding, and as it does not permit one to approach very near, it has been impossible to settle the point. I have endeavoured to study the matter further by starving flies in captivity, providing them only with wet sand, but even though they survived longer than a similar number kept entirely without water, I was not quite sure even then that they did drink, though I thought I saw one or two do so.

I have endeavoured to test also whether flies ever drink dew, and whether they will feed on various fruit juices, saline solution, etc., but have not obtained any positive results.

Though there seems to be some evidence that the flies are attracted to a moving object through the sense of sight, I have found repeatedly that if well starved flies with one wing clipped are released in long grass, they will make their way by running to a person sitting at a distance of ten to twelve feet, whom it is impossible for them to have seen. The sense of smell therefore must play an important part in leading them to their prey. But the smell of fresh blood does not have the effect of attracting flies, for I smeared the blood of a freshly shot duiker antelope, and on another occasion the blood of a fowl, on trees in the fly area and none came to it, though there was a breeze blowing and a fair number of flies were in the neighbourhood.

Conversely, flies with their antennae snipped off at the base with fine scissors, which does not seem to make any material difference to their well being in captivity, have been found in a few instances to make their way to a moving person from a short distance, ten to fifteen yards.

A further series of flies following at one's heels in the early morning and evening and settling on the ground from time to time, but not attempting to bite, have been secured; all have been males. As has been repeatedly noted by other observers, male flies settle sometimes on one's back and do not attempt to bite, an occurrence in my experience more frequent in the heat of the day. The interpretation of this habit is, I believe, that the ground, which is then so hot as to be unpleasant even to the feet protected by thick boots, is too scorching for the flies, which then avail themselves of the coolest situation convenient. I have endeavoured to obtain some evidence as to whether such flies really are on the look out for females only, by causing boys to carry on their backs as they walked through fly country newly emerged female flies gummed by the legs on brown paper, but no results were obtained, though as the male seizes the female while on the wing, no negative inference can be drawn from the experiment.

Observations on *Glossina brevipalpis*.

This species was found in February to occur in a very limited area in the centre of the Lingadzi estate, which is situated on either bank of the river of that name, about eight miles from Lake Nyasa. The estate is surrounded on three sides by dense bush, but towards the east is more open, consisting of thin woods interspersed with dambos. It was at one time used as a cattle station, but the enterprise was abandoned some years ago owing to the advent of *morsitans*, and now a limited portion only, some ten or twelve acres, is under cultivation for fruit.

G. brevipalpis to the number of ten to fifteen, all males, were taken night after night at about dusk in the fruit garden within an area of about fifty square yards, mostly along a path running through it from the bank of the river. The fruit trees growing at the spot were bananas, mangoes, and citrus fruits; three large indigenous trees, one evidently allied to our plane tree, being the only others therein. The area was devoid of weeds and undergrowth, except for a broad belt of coarse high grass growing in the mud of the river bank. The soil was a well-drained rich black humus, except along the path, where, owing to the lighter portions having been washed away, some sand was in evidence.

A systematic and very careful attempt was made day after day to discover why the fly was present and in so limited a space, but no light was obtained on the question. As the rains were on there was no difficulty in examining the spoor of animals passing through the area, and this was done for a fortnight. The foot-prints of duiker antelope were found very commonly, and on one occasion those of a kudu, and so far as could be ascertained these were the only large animals which passed through it during this time. Toads occurred in some numbers, and an attempt was made by keeping some in captivity to ascertain if the flies ever fed on them. They did not do so, but were gradually caught and eaten by the toads. An endeavour was made also to ascertain if the flies would feed on fruit and fruit juices, but no results were obtained.

No female flies at all were taken among a total of 119 flies, neither were any pupae found, though sought for in every conceivable situation—at the bases of all the trees, high up in the forks of the larger trees, in the debris around the bananas, in the

sandy soil of the path and in the mud of the river bank. A few females were found in the daytime, resting low down on the tree-trunks, and one was taken at 10 a.m. in a well shaded nook off the leg of a boy who called my attention to it, saying that it had bitten him, and I found that it was distended with fresh blood.

Fifteen of the flies were placed in captivity on 12th February and were afforded an opportunity daily of feeding on the blood of a goat. On this diet they thrived for fourteen days, during which two only died; then a large number of small black ants made a raid on them and killed nine before they were discovered. The remaining three died off one by one, the last nine days later, having accordingly lived on goat's blood solely for twenty-three days.

The other habits of the species were found to accord with those described by other observers.

An attempt was made by releasing marked flies near by to ascertain whether they would return to this particular spot, but none were ever recovered.

Later on, an opportunity was taken to study *Glossina brevipalpis* in its haunts nearer Lake Nyasa. The locality there affected by it lies for some three or four miles along the Lake shore between the two mouths of the river Lingadzi, and on either bank for three or four miles inland, and it is characterised by the great density of its vegetation, a large variety of shrubs, herbaceous plants, and tall grasses, all laced together by several species of convolvulus, and leguminous climbers, the irritating *Mucuna* bean in particular, growing beneath large trees of the *Acacia* type, from the branches of which depend lianas. The bush is here far thicker than I have seen it elsewhere in the country and reminds one of that seen in the coastal belt of tropical West Africa.

The soil is light and sandy, and contains even now, after four months drought, plenty of moisture, so that along paths cleared only three weeks ago the young grass is already ankle-high and I am informed that it is not as a rule possible to burn it off till October or November, when the rains are again due.

There are several villages, the inhabitants of which have cleared large garden plots, and in some of these even at this season young maize, planted in depressions hollowed in the ground, is thriving, though rather dwarfed in growth.

This bush is traversed by numerous winding game paths, and it affords shelter to a large variety of game animals, in fact, I found the fly first along a game path down which a herd of waterbuck had just passed on their way to the lake.

I believe that the presence of this species of fly is conditioned solely by the presence of dense vegetation, affording at all times adequate shade and the gloom favourable to an insect of crepuscular habits. Its presence on the Lingadzi estate where indigenous trees are practically absent, and where these conditions are obtained through closely planted and untrimmed evergreen citrus and other fruit trees, would seem to indicate that its presence is not influenced by any special kind of vegetation.

When endeavouring to discover the breeding grounds of this fly, my attention was at first naturally concentrated on places similar to those utilised by *morsitans*, and in some of these, under the shelter of fallen dead trees, I found pupa-cases

both of *morsitans* and of *brevipalpis*, never more than three or four of each. But on removing the low, thickly growing vegetation at a spot well sheltered by the foliage of the large trees, I obtained in the course of a two days' search over an area about twenty-five yards square no less than 507 pupa-cases and seven living pupae. This spot differed in regard to soil and vegetation in nowise, so far as I could ascertain, from the rest of the neighbourhood, but it was traversed by a path along which game is evidently in the habit of passing to and from the water, and moreover it is close to the edge of a sandy bank (the original edge of the lake, which is gradually receding), and I imagine it to be probable that beasts may loiter there as a measure of caution before descending into more open country, as a result of which replete female flies, incapable of prolonged flight, would shelter there. More pupae have been found in similar situations, 109 pupa-cases in one place, and 4 pupae and 54 cases in another. I expect that the small number of living pupae hitherto found may be explained by the breeding season being over. As with the pupae of *morsitans* there is some variation in regard to size.

Some of the flies have emerged from the pupae ; all, as was to be expected, in the late afternoon ; one, a female, attempting to do so tail end first, a condition not unfrequently seen also with *morsitans*.

Small round holes, indicating probably the escape of larger Chalcids, were seen in four pupa-cases only out of a total of 737. No other evidence of parasitism was obtained by an examination of the cases, but on placing one of the pupae in a jar containing a female *Mutilla glossinae* with *morsitans* pupae, the Mutillid unhesitatingly bored a hole in the usual way and oviposited in it.



Fig. 1. Haunts of *Glossina morsitans*; flat country covered with short grass and clumps of *Borassus* palms and low shrubs.



Fig. 2. Haunts of *Glossina morsitans*; flat country covered with very tall grass and clumps of large shade trees.



Fig. 1. Haunts of *Glossina morsitans*; higher rocky ground covered with short grass and stunted bush.



Fig. 2. A breeding place of *Glossina morsitans*; at the point indicated by the piece of paper 7 living puparia and 4 empty cases were found.



Fig. 1. A breeding place of *Glossina morsitans*; in the four spots indicated by slips of paper 14 fresh and 15 old puparia were found; the stones were situated among high grass.



Fig. 2. Under a dead tree in the bushes to the left 11 fresh and 79 old puparia of *Glossina morsitans* were found.